



The Nervous System: Neurons and Synapses

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Nervous System

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- 2 types of cells in the nervous system:
 - **Neurons.**
 - **Supporting cells (Neuroglia - CNS).**
- Nervous system is divided into:
 - Central nervous system (CNS):
 - **Brain.**
 - **Spinal cord.**
 - Peripheral nervous system (PNS):
 - **Cranial nerves.**
 - **Spinal nerves.**



Neurons

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- Basic structural and functional units of the nervous system.
 - *Cannot divide by mitosis.*
- Respond to *physical* and *chemical stimuli*.
- Produce and conduct *electrochemical impulses*.
- Release *chemical regulators*.
- **Nerve:**
 - Bundle of axons located outside CNS.
 - Most composed of both motor and sensory fibers.



Neurons (continued)

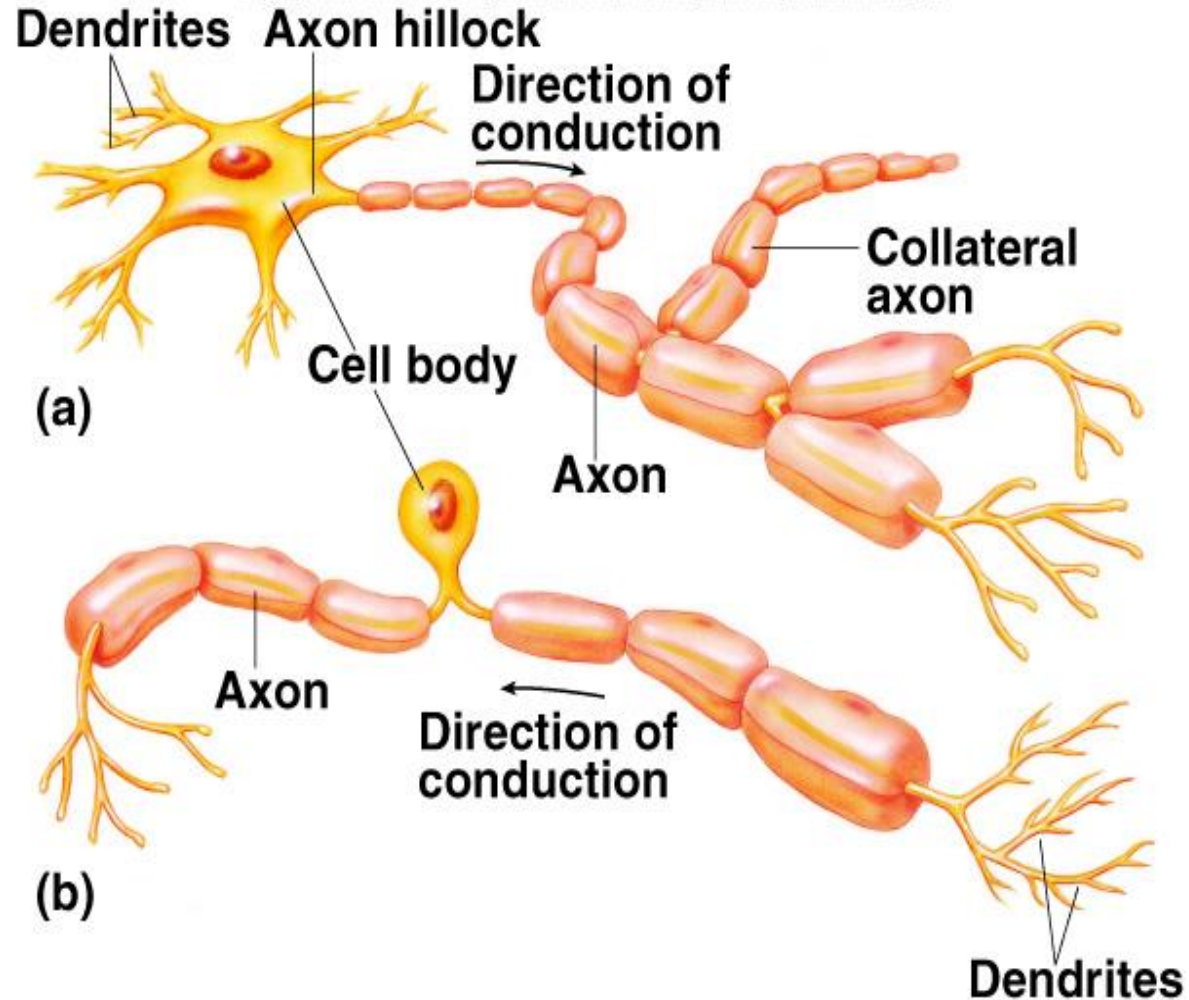
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- **Cell body** (perikaryon):
 - "Nutrition center."
 - Cell bodies within CNS clustered into nuclei, and in PNS in ganglia.
- **Dendrites:**
 - Provide receptive area.
 - Transmit electrical impulses to cell body.
- **Axon:**
 - Conducts impulses away from cell body.
 - Axoplasmic flow:
 - Proteins and other molecules are transported by rhythmic contractions to nerve endings.
 - Axonal transport:
 - Employs microtubules for transport.
 - May occur in orthograde or retrograde direction.

Neurons (continued)

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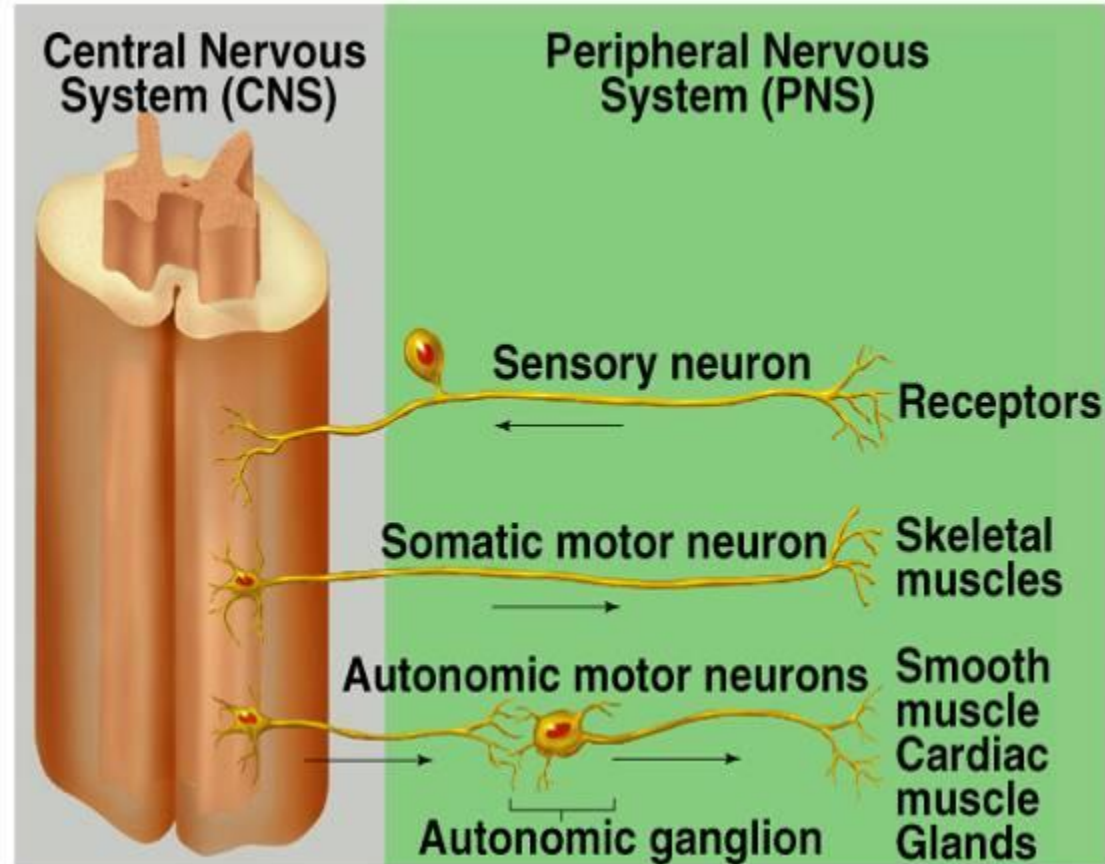


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Functional Classification of Neurons

- Based upon direction impulses conducted.
- **Sensory or afferent:**
 - Conduct impulses from sensory receptors into CNS.
- **Motor or efferent:**
 - Conduct impulses out of CNS to effector organs.
- **Association or interneurons:**
 - Located entirely within the CNS.
 - Serve an integrative function.

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Structural Classification of Neurons

■ Based on the # of processes that extend from cell body.

■ **Pseudounipolar:**

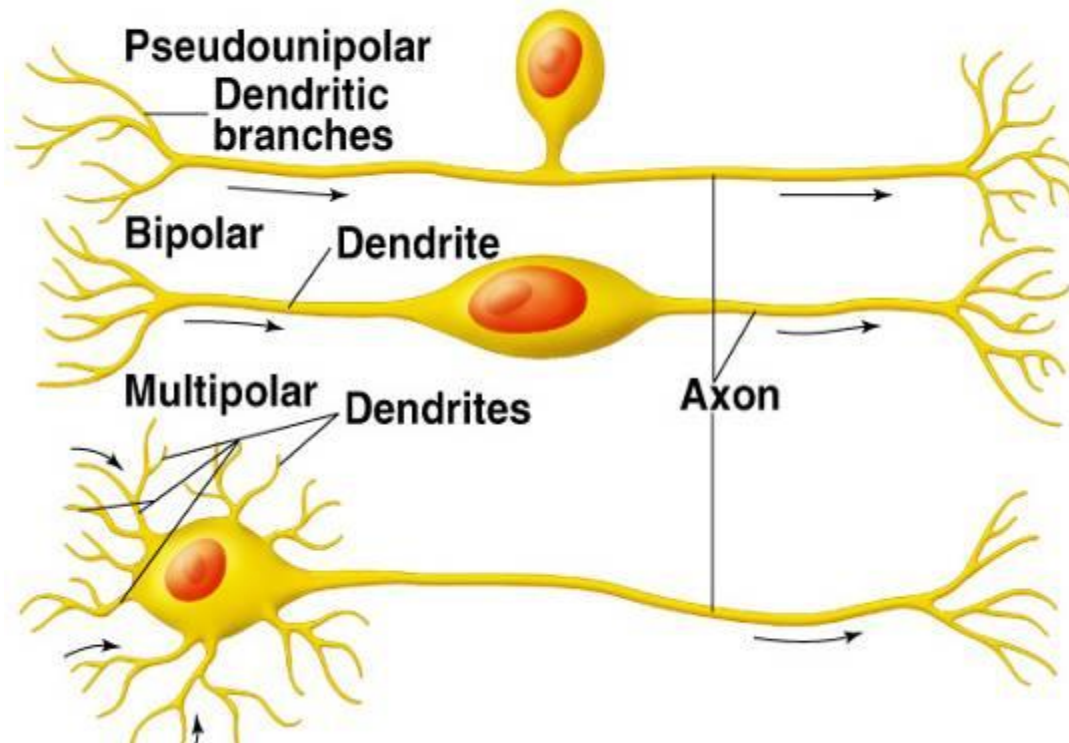
- Short single process that branches like a T.
 - Sensory neurons.

■ **Bipolar** neurons:

- Have 2 processes.
 - Retina of the eye.

■ **Multipolar:**

- Have several dendrites and 1 axon.
 - Motor neuron.



PNS Supporting Cells

■ Schwann cells:

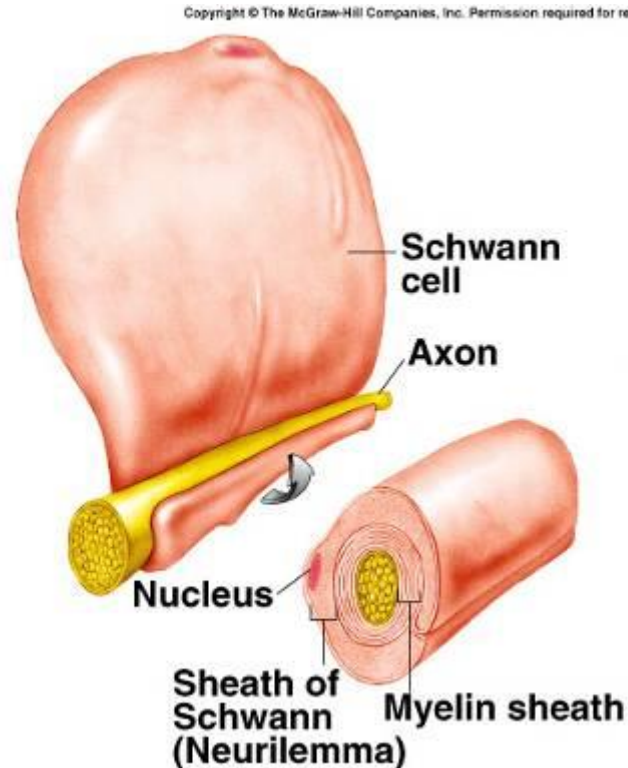
- Successive wrapping of the cell membrane.
- Outer surface encased in glycoprotein basement membrane.
- Provide insulation.

■ Nodes of Ranvier:

- Unmyelinated areas between adjacent Schwann cells that produce nerve impulses.

■ Satellite cells:

- Support neuron cell bodies within ganglia.



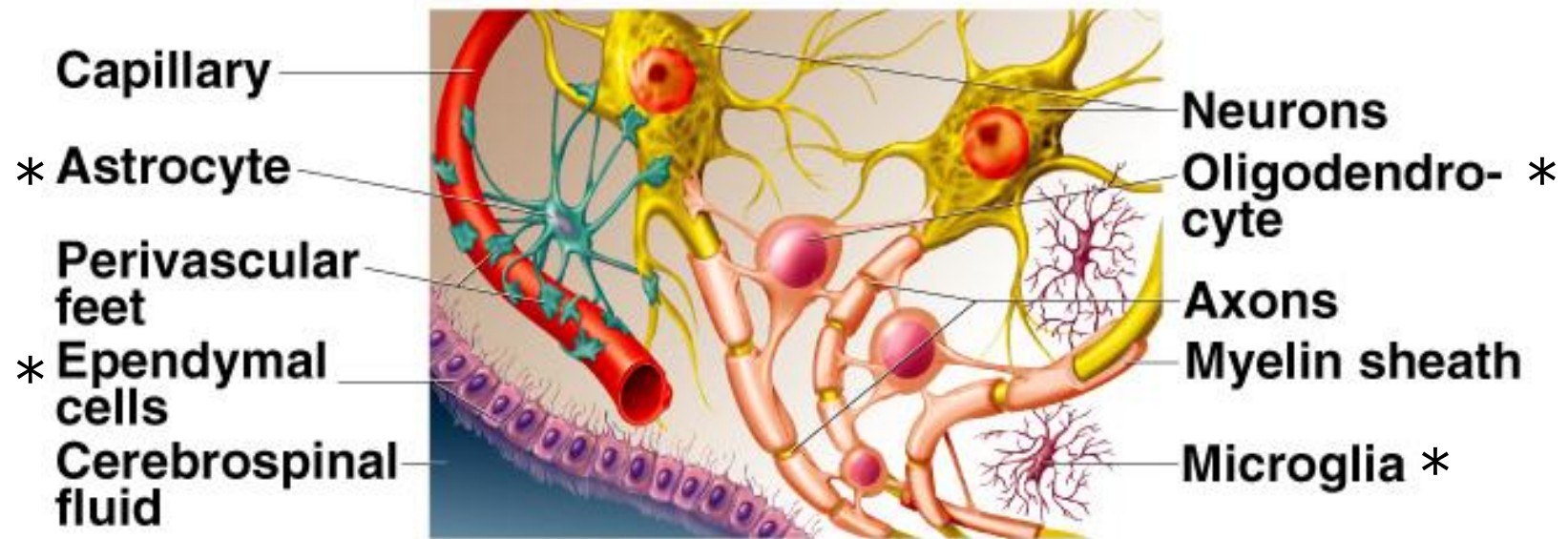
CNS Supporting Cells

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Neuroglia are the supporting cells of the CNS.

* Astrocytes, Ependymal Cells, Oligodendrocytes, & Microglia.



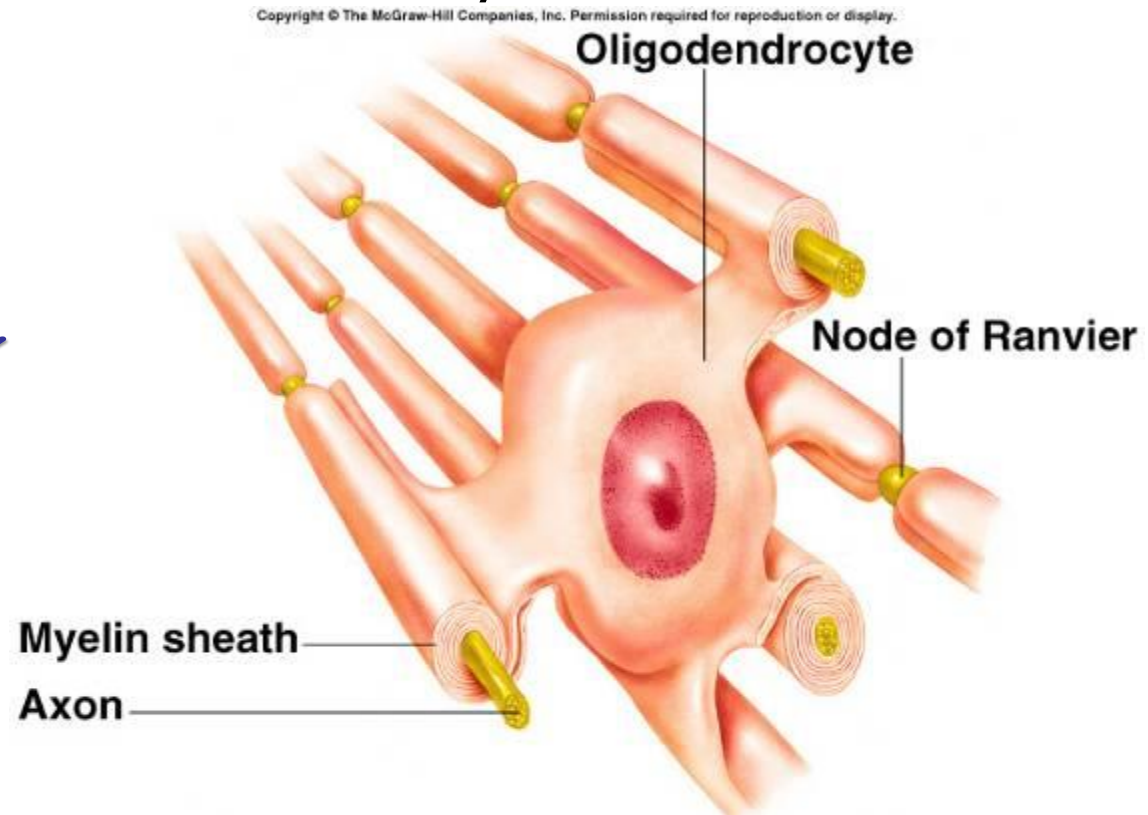
CNS Supporting Cells

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■ Oligodendrocytes:

- Process occurs mostly postnatally.
- Each has extensions that form myelin sheaths around several axons.
 - Insulation.

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Nerve Regeneration

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■ Schwann cells:

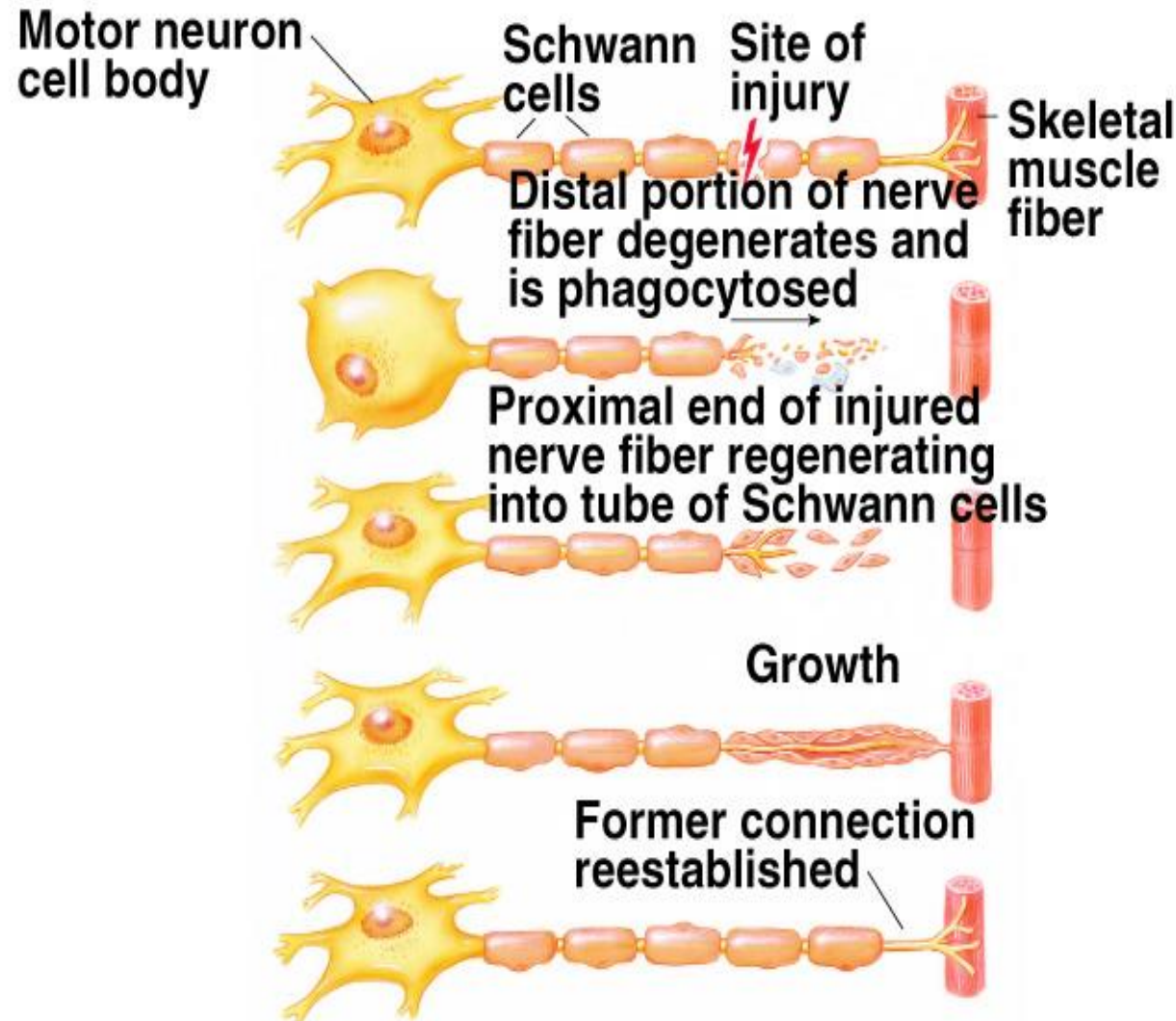
- Act as *phagocytes*, as the distal neuronal portion degenerates.
- Surrounded by basement membrane, form *regeneration tube*:
 - Serve as guide for axon.
 - Send out chemicals that attract the growing axon.
 - Axon tip connected to cell body begins to grow towards destination.

Nerve Regeneration (continued)

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■ *CNS has limited ability to regenerate:*

- Absence of continuous basement membrane.
- Oligodendrocytes molecules inhibit neuronal growth.





Neurotrophins

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- Promote neuron growth.
- **Nerve growth factors** include:
 - Nerve growth factor (NGF), brain-derived neurotrophic factor (BDNF), glial-derived neurotrophic factor (GDNF), neurotrophin-3, and neurotrophin-4/5.
- Fetus:
 - Embryonic development of sensory neurons and sympathetic ganglia (NGF and neurotrophin-3).



Neurotrophins (continued)

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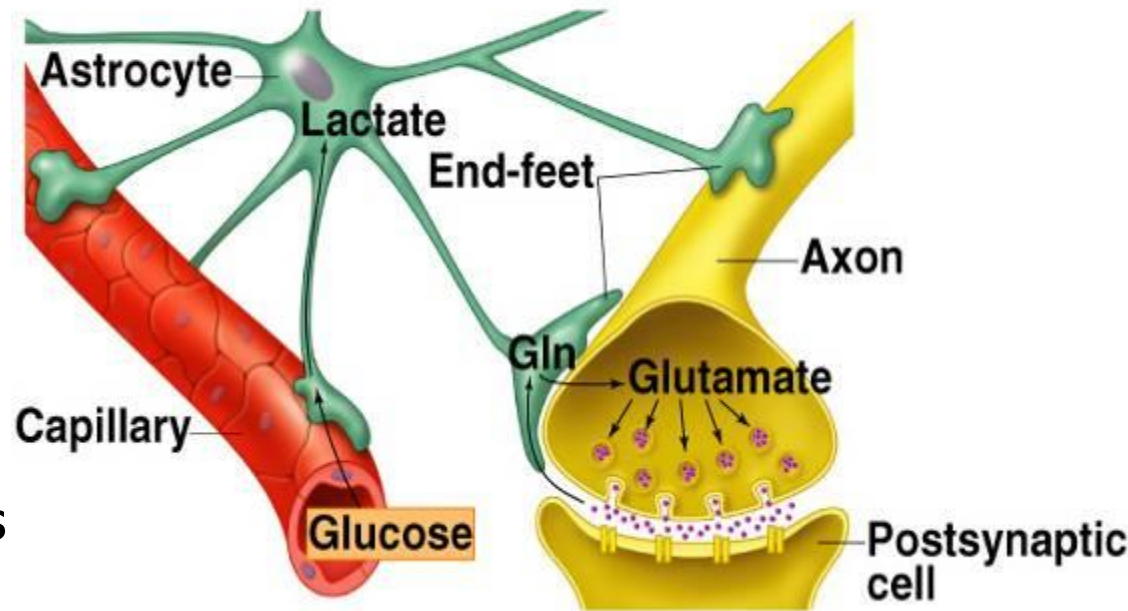
- Adult:
 - Maintenance of sympathetic ganglia (**NGF**).
 - Mature sensory neurons need for regeneration.
 - Required to maintain spinal neurons (**GDNF**).
 - Sustain neurons that use dopamine (**GDNF**).
- **Myelin-associated inhibitory proteins:**
 - Inhibit axon regeneration.

CNS Supporting Cells (continued)

■ Astrocytes:

- Most abundant glial cell.
- Vascular processes terminate in end-feet that surround the capillaries.
- Stimulate tight junctions, contributing to **blood-brain barrier**.
- Regulate external environment of K^+ and pH.
- Take up K^+ from ECF, NTs released from axons, and lactic acid (convert for ATP production).
 - Other extensions adjacent to synapses.

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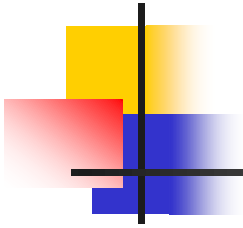




CNS Supporting Cells (continued)

- Microglia:
 - Phagocytes, migratory.
- Ependymal cells:
 - Secrete CSF.
 - Line ventricles.
 - Function as neural stem cells.
 - Can divide and progeny differentiate.

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Blood-Brain Barrier

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- Capillaries in brain do not have pores between adjacent endothelial cells.
 - Joined by tight junctions.
- Molecules within brain capillaries moved selectively through endothelial cells by:
 - *Diffusion.*
 - *Active transport.*
 - *Endocytosis.*
 - *Exocytosis.*



Electrical Activity of Axons

- All cells maintain a **resting membrane potential (RMP)**:
 - *Potential voltage difference across membrane.*
 - Largely the result of negatively charged organic molecules within the cell.
 - Limited diffusion of positively charged inorganic ions.
 - *Permeability of cell membrane:*
 - Electrochemical gradients of Na^+ and K^+ .
 - Na^+/K^+ ATPase pump.
- **Excitability/irritability:**
 - *Ability to produce and conduct electrical impulses.*

Electrical Activity of Axons (continued)

- Increase in membrane permeability for specific ion can be measured by placing 2 electrodes (1 inside and 1 outside the cell).

- **Depolarization:**

- Potential difference reduced (become more positive).

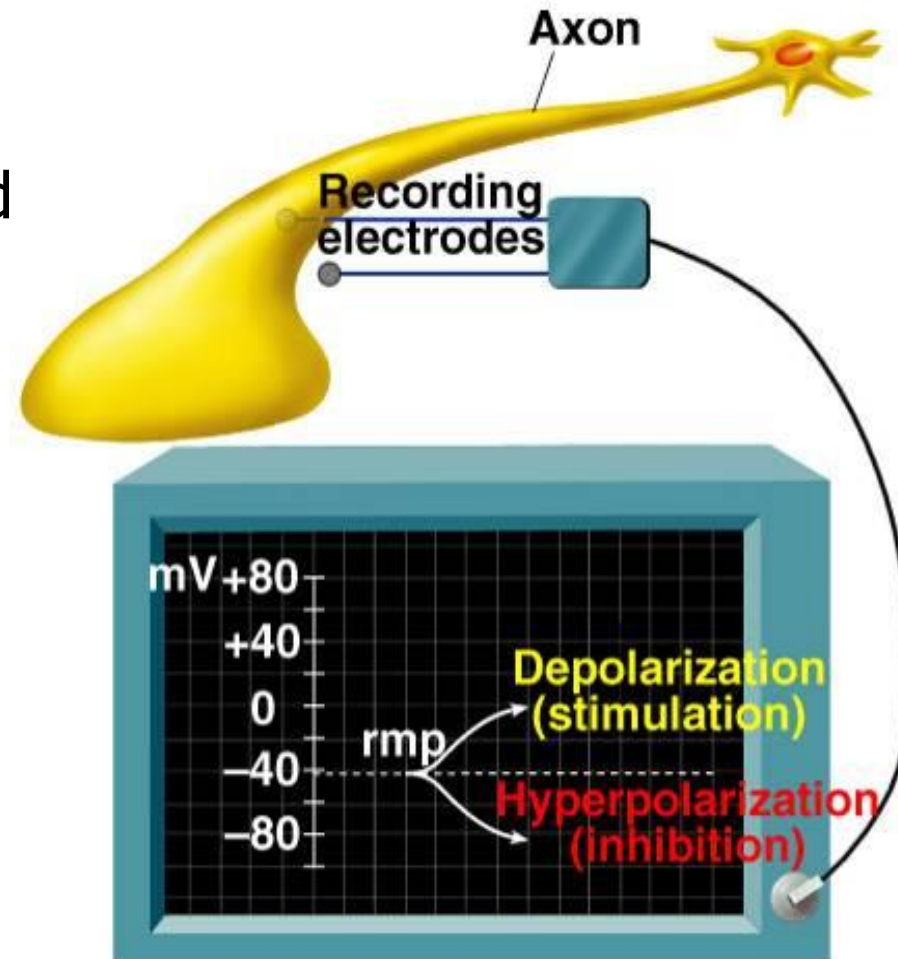
- **Repolarization:**

- Return to resting membrane potential (become more negative).

- **Hyperpolarization:**

- More negative than RMP.

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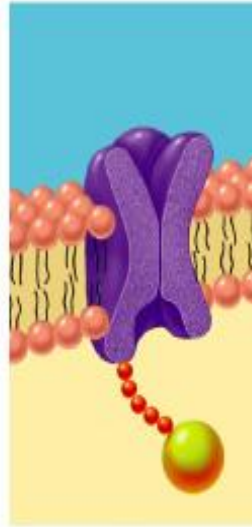
Ion Gating in Axons

- Changes in membrane potential caused by ion flow through ion channels.
- **Voltage gated (VG) channels** open in response to change in membrane potential.
 - Gated channels are part of proteins that comprise the channel.
 - Can be open or closed in response to change.
 - 2 types of channels for K^+ :
 - 1 always open.
 - 1 closed in resting cell.
 - Channel for Na^+ :
 - Always closed in resting cells.
 - Some Na^+ does leak into the cells.

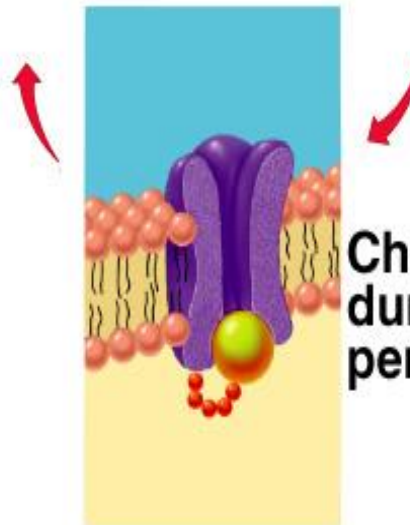
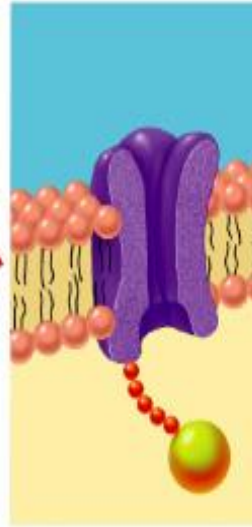
Ion Gating in Axons (continued)

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Channel closed at resting membrane potential



Channel open by depolarization (action potential)



Channel inactivated during refractory period

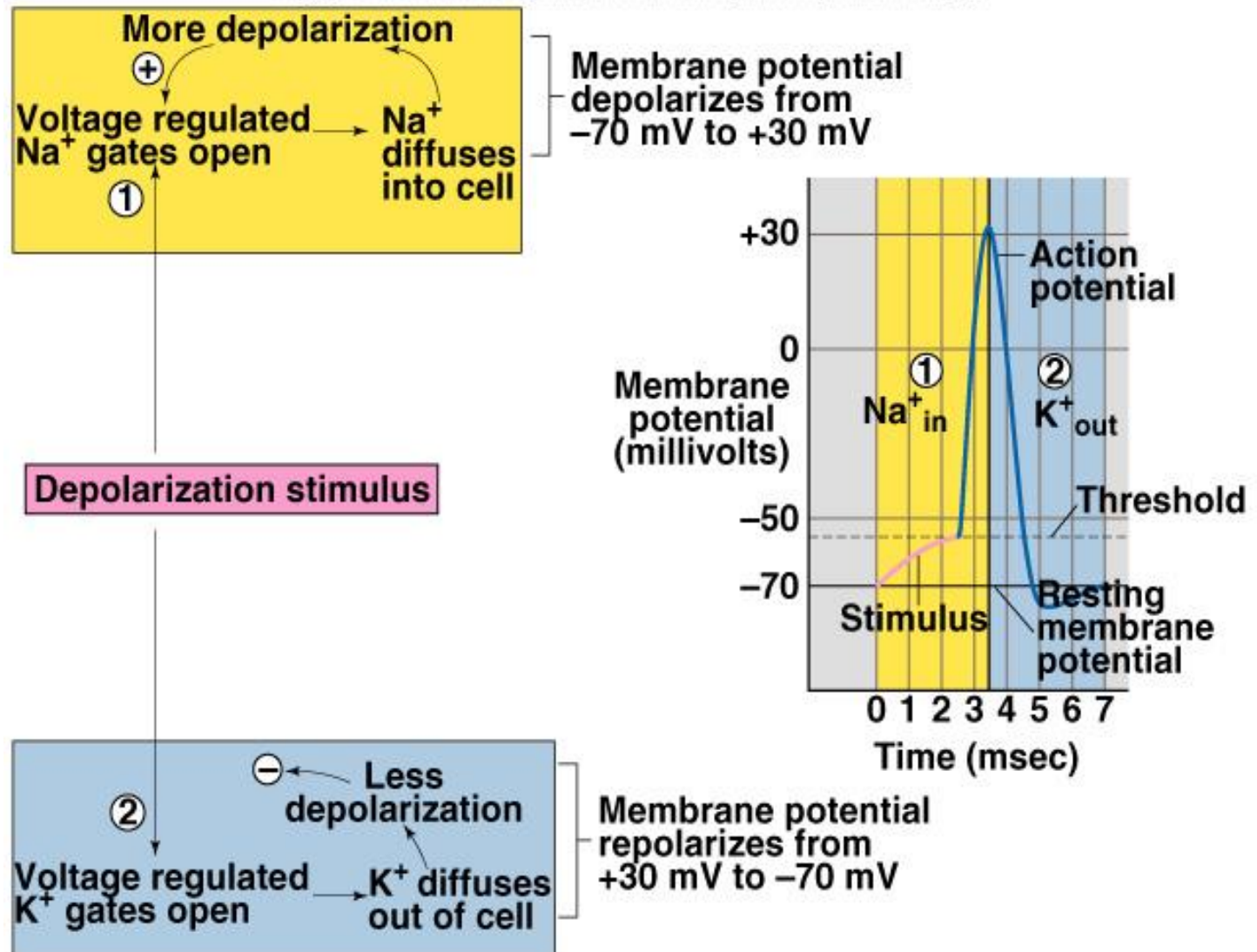
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Action Potentials (APs)

- Stimulus causes depolarization to threshold.
- VG Na⁺ channels open.
 - Electrochemical gradient inward.
 - + feedback loop.
 - Rapid reversal in membrane potential from -70 to +30 mV.
 - VG Na⁺ channels become inactivated.
- VG K⁺ channels open.
 - Electrochemical gradient outward.
 - - feedback loop.
 - Restore original RMP.

Action Potentials (APs) (continued)

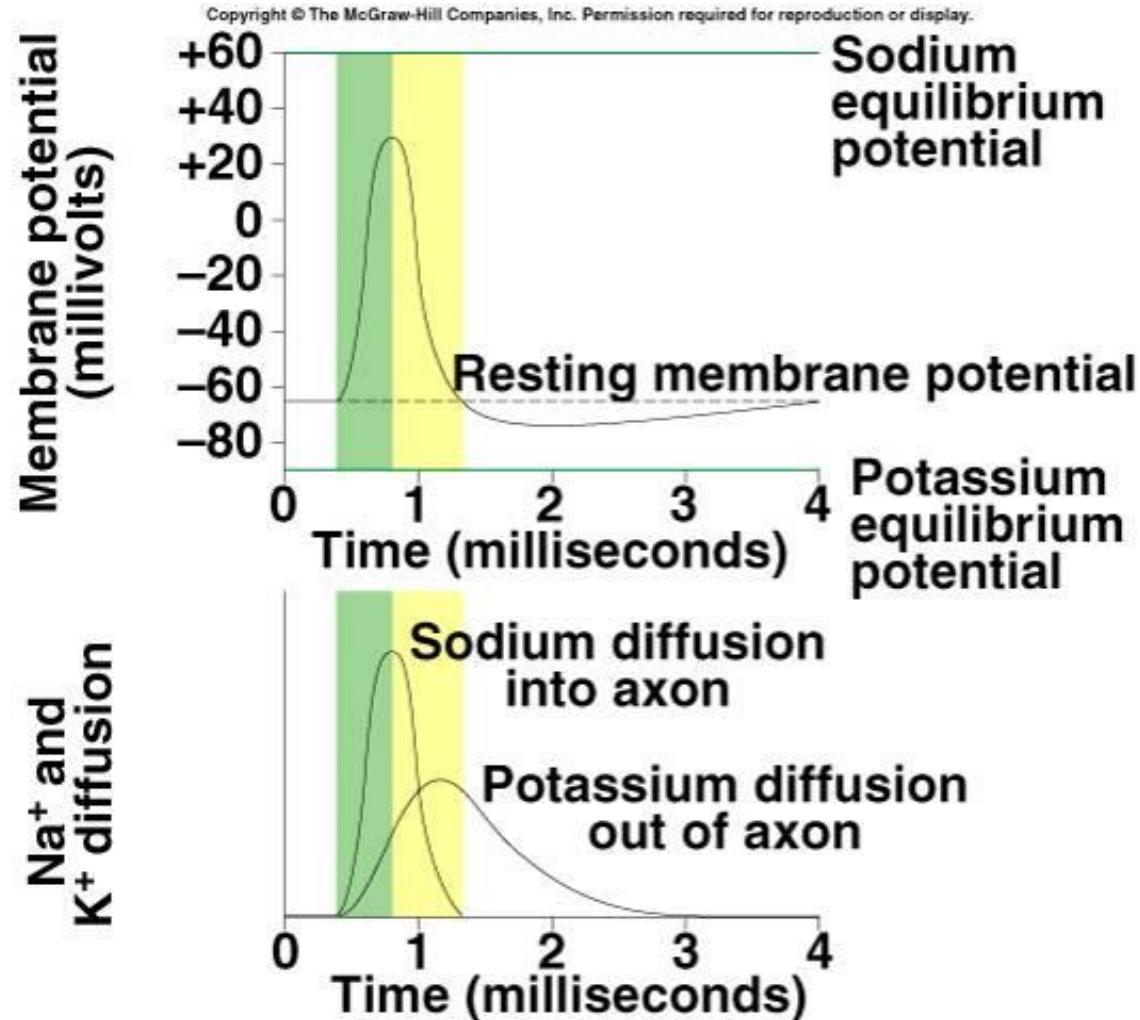
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Membrane Permeabilities

- AP is produced by an increase in Na^+ permeability.
- After short delay, increase in K^+ permeability.

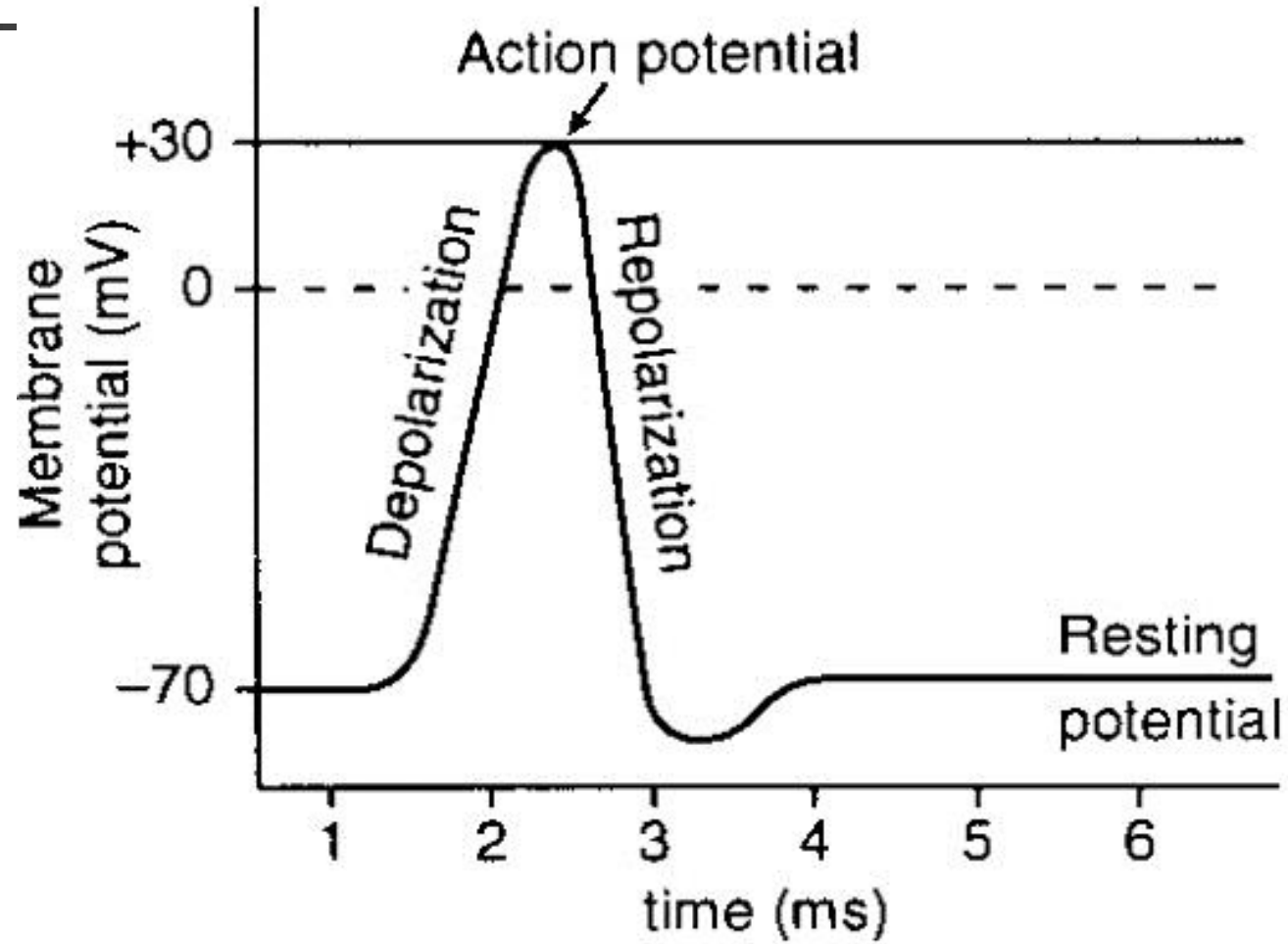
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Action Potentials (APs) (continued)

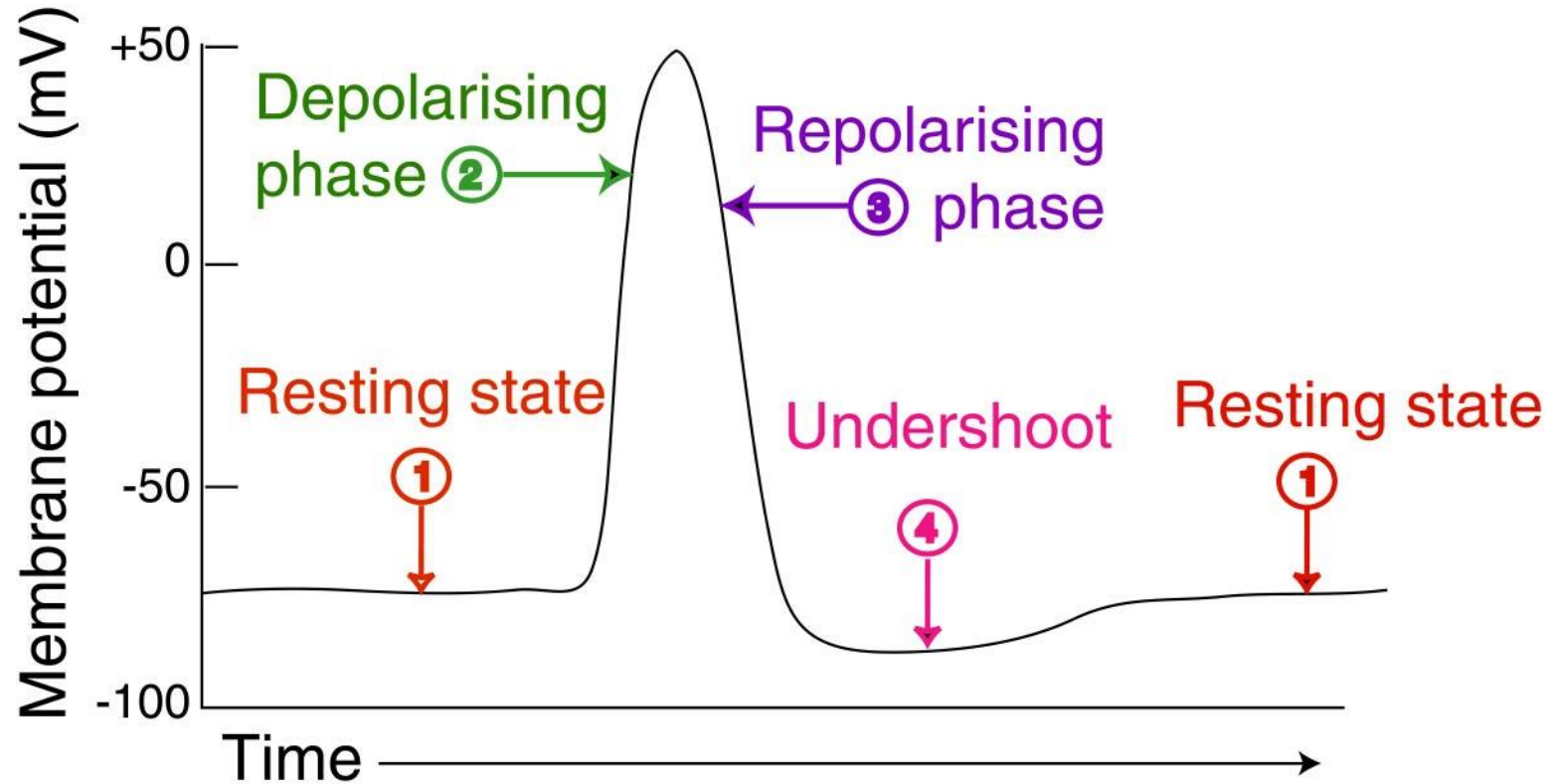
- **Depolarization and repolarization** occur via **diffusion**, do not require active transport.
 - Once AP completed, Na^+/K^+ ATPase pump extrudes Na^+ , and recovers K^+ .
- **All or none:**
 - When threshold reached, maximum potential change occurs.
 - Amplitude does not normally become more positive than + 30 mV because VG Na^+ channels close quickly and VG K^+ channels open.
 - Duration is the same, only open for a fixed period of time.
- **Coding for Stimulus Intensity** (Fig. 7.15):
 - Increased frequency of AP indicates greater stimulus strength.
- **Recruitment:**
 - Stronger stimuli can activate more axons with a higher threshold.

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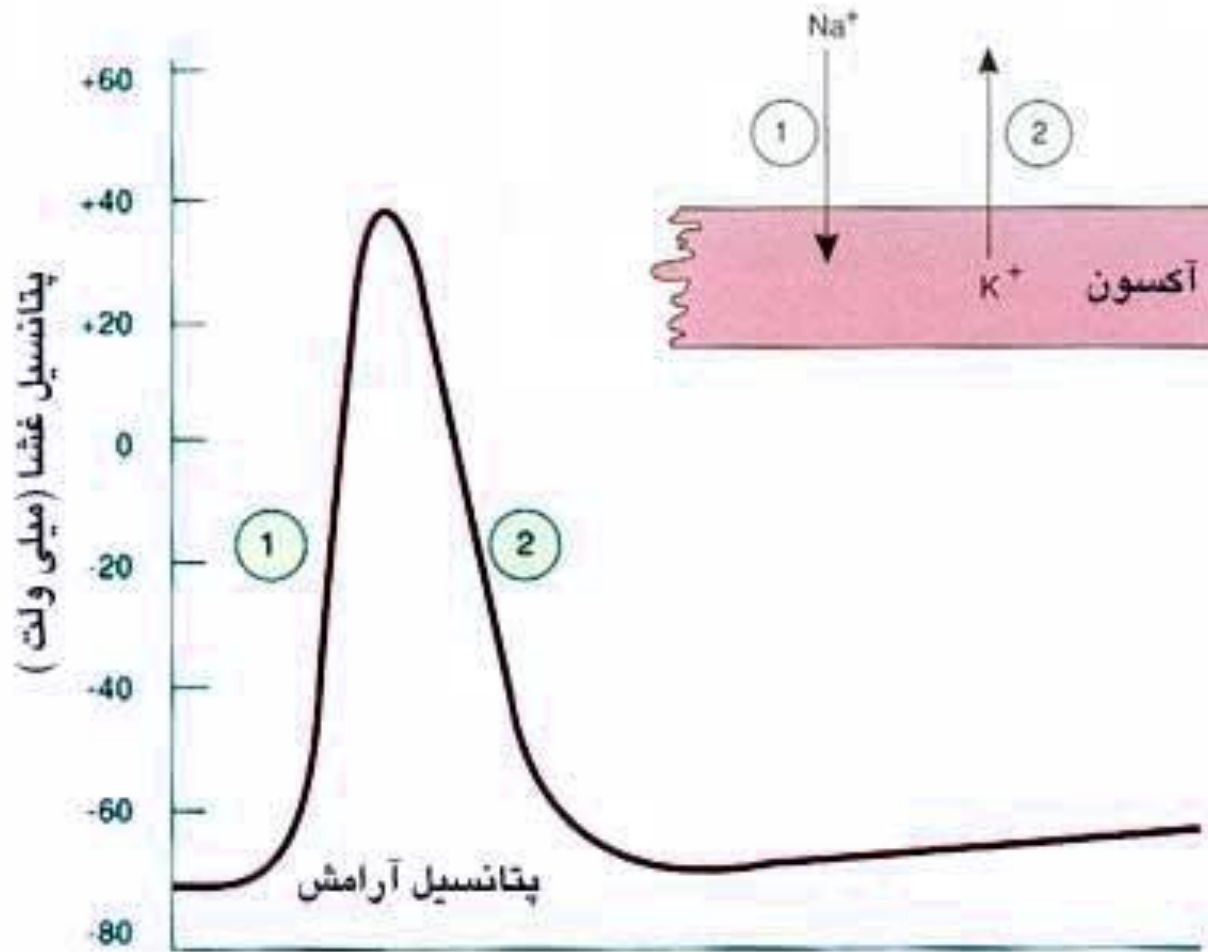


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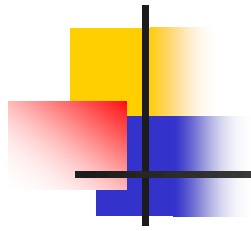


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